Programmable Syringe Flow Regulator

By

Margarette G. Castisimo

Jessica Camille D. Docog

Louisse Philipp P. Leocadio

Raymond P. Pariñas

Vincent S. Quitlong Jr.

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This is to certify that we have supervised the preparation of and read the design report prepared by **Margarette Castisimo, Jessica Camille Docog, Louisse Philipp Leocadio, Raymond Pariñas** and **Vincent Quitlong Jr.** entitled **Programmable Syringe Flow Regulator** and that the said report has been submitted for final examination by the Oral Examination Committee.

Prof. Benigno B. Agapito Jr.
Reader

Engr. Jocelyn F. Villaverde
Design Adviser

As members of the Oral Examination Committee, we certify that we have examined this design report presented before the committee on **September 8, 2009,** and hereby recommend that it be accepted as fulfillment of the design requirement for the degree in **Bachelor of Science in Computer Engineering.**

Engr. Jessie R. Balbin
Panel Member

Engr. Gorgonio C. Vallestero II
Panel Member

Engr. Kevin B. Dagbay
Panel Member

This design is hereby approved and accepted by the School of Electrical Engineering, Electronics and Communications Engineering, and Computer Engineering as fulfillment of the design requirement for the degree in **Bachelor of Science in Computer Engineering.**

Dr. Felicito S. Caluyo
Dean, School of EE-ECE-CoE

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Margarette G. Castisimo

Jessica Camille D. Docog

Louisse Philipp P. Leocadio

Raymond P. Pariñas

Vincent S. Quitlong Jr.

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ABSTRACT

The Programmable Syringe Flow Regulator is a device that regulates a constant flow rate of the liquid depending on the specified time required for its use. This design is originated to develop an innovative way of using syringes common in the market to help those people in the medical field as well as researchers that will need this device on their experiments. The device is composed of helical screw, linear guide, aluminum bar and an angle bar that will hold the syringe and a stepper motor.

Keywords: programmable, syringe, flow rate, regulator, microcontroller

Chapter 1

DESIGN BACKGROUND AND INTRODUCTION

This chapter discusses a brief introduction about the design; the problems and the objectives identified by the researchers; the significance of the study to its possible users; and the scope and delimitation of the design.

DESIGN SETTING

Syringes commonly available in the market nowadays are those we see in the hospitals that are used as a medical tool. Moreover, it can be used in researches since it is also a measuring tool used to transfer liquids from one container to another. It is manually operated resulting to inconstant force applied on the plunger thus having an irregular flow of liquid. This kind of manual operation of syringe when used in research development may lead to inappropriate results which is at far behind of what is being expected. The market today offers a wide variety of these types of syringes but the price is way higher than an individual can afford to. Also market-based products are already made products that cannot be modified or be customized on the way the consumer wants them to be.

STATEMENT OF THE PROBLEM

Because of the fast changing technology people tend to search, if not, they develop equipment that will help them do their work conveniently and at the same time to come up with desirable results. Syringes that are commonly available in the market are manually operated, thus, resulting to irregular flow of liquid. Another problem is when a researcher conducting experiments involving liquid tests wants to have a device that will enable him to control a constant liquid flow rate thus, giving a more acceptable test results.

OBJECTIVE OF THE DESIGN

The main objective of the design is to create a programmable syringe flow regulator that can dispense solutions with varying viscosity. Listed below are the specific objectives of the research:

1. To show that the volume of different liquid dispensed in a given time is constant; and
2. To develop a low-cost programmable syringe flow regulator compared to market-based products.

SIGNIFICANCE OF THE STUDY

Programmable Syringe Flow Regulator is a prototype that can be used in research – related experiments. It can be used in experiments needed in biomedical researches, in hospitals and even in school laboratories.

This study will benefit researchers especially those on chemical or drug researches. The development of the programmable syringe regulator will help them make their tests and experiments be automated and achieve a more acceptable test results.

Schools will also benefit on this innovation since it can be used in chemical laboratories. Economically, the country will benefit on this study since all materials used are bought locally which are quite cheap. Thus duplicating and making this device is easy.

Users can be assured that the programmable syringe regulator is user friendly.

CONCEPTUAL FRAMEWORK

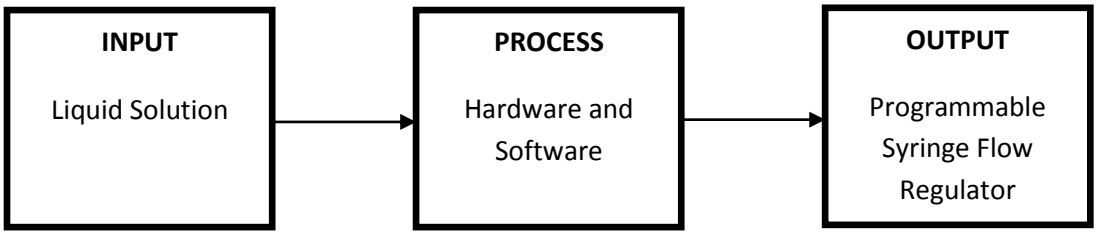

Figure 1.1 Conceptual Framework

The figure shows the concept of our design. The liquid is placed on the syringe then inserted in the bar. The user then enters the desired flow rate and time when the liquid is all dispersed. By pressing the start button, the inputted values are implemented and the helical screw is started to move that pushes the syringe until it reaches the other end of the aluminum bar and the syringe is empty. It informs the user if the process is done by its sound and pushes the syringe to its starting point.

SCOPE AND DELIMITATIONS

The device covers and delimits the following:

Scope of the Design:

1. Flow rate ranges from 0.1 mL/min to 9.9 mL/min which are the minimum and maximum rates respectively.
2. It can output the desired rate of the user in one minute.
3. Syringe can be filled with liquid manually.

4. The device will still function regardless of its position.

Delimitation of the Design:

1. The syringe flow regulator can only hold a 5cc syringe.
2. The syringe holder can only contain one syringe at a time.
3. The device has no scheduler wherein it does not automatically start and stop to run.
4. The device has no pause function and will continue its work until the liquid is completely consumed.

DEFINITION OF TERMS

Buffer – Creates an output equal to the input. It also serves as a signal refresher to strengthen any weak signal output (Floyd, 2006).

Calibrate – To check, adjust, or determine the graduations of a quantitative measuring instrument by comparison with a standard (Pyzdek and Keller, 2003).

Delay – Change in an output in response to the change of an input occurs after a specified propagation delay (Mano and Kime, 2003).

Driver – A small piece of software that tells the operating system and other software how to communicate with a piece of hardware (Mano and Kime, 2003).

Flow Rate – The amount of fluid that flows in a given time (Sherman and Russikoff, 1996).

Input – The signal or line going into a circuit; a signal that controls the operation of a circuit (Floyd, 2006).

Keypad – Used to enter information to the computer (Mano and Kime, 2003).

Liquid – The physical state of matter in which particles are held together but are free to move about. It has a definite volume but takes

the shape of the container in which they are placed (Sherman and Russikoff, 1996).

Microcontroller – A specialized microprocessor designed for control functions (Floyd, 2006).

Microprocessor – A digital integrated circuit device that can be programmed with a series of instructions to perform specified functions on data (Mano and Kime, 2003).

PIC (Programmable Interrupt Controller) - Handles interrupts on a priority basis. It accepts service requests from the peripherals (Mano and Kime, 2003).

Plunger – Part of the syringe responsible for creating the vacuum to draw up liquids and then to discharge them (Dorland and Rhodes, 2002).

Power Supply – A system that converts AC current from the wall outlet into the DC currents required by electronic circuits (Bakshi and Godse, 2004).

Programmable – Capable of being programmed for computer processing (Floyd, 2006).

PSOC (Programmable System-on-Chip) – A family of mixed-signal arrays made by Cypress Semiconductor, featuring a microcontroller

and configurable integrated analog and digital peripherals. PSoC is a software configured, mixed-signal array with a built-in MCU core.

Pulley – A mechanism composed of a wheel with a groove between two flanges around the wheel's circumference. Pulleys are used to change the direction of an applied force, transmit rotational motion, or realize a mechanical advantage in either a linear or rotational system of motion (Beer and Mazurek, 2008).

Regulator – Keeps the output voltage constant inspite of changes in load current of input voltage (Bakshi and Godse, 2004).

Reset – The state of a flip-flop or latch when the output is 0; the action of producing a RESET state (Mano and Kime, 2003).

Speed – The particle's displacement divided by the time interval during which that displacement occurs (Servay and Jewett, Jr., 2004).

Stepper Motor – A brushless, synchronous electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely, without any feedback mechanism.

Syringe – A device used in medicine to inject fluid into or withdraw fluid from the body. Medical syringes consist of a needle attached to a hollow cylinder that is fitted with a sliding plunger. The downward

movement of the plunger injects fluid; upward movement withdraws fluid (Dorland and Rhodes, 2002).

Time – The time interval between two events measured by an observer who sees the events occurs at the same point in space (Servay and Jewett, Jr., 2004).

Transformer – A device that is mostly used to change the voltage in an alternating current (AC) (Bakshi and Godse, 2004).

Viscosity - Describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction (Potter and Wiggert, 1990).

Volume – A measure of the capacity of a three-dimensional object. (Sherman and Russikoff, 1996).

Chapter 2

REVIEW OF RELATED LITERATURE AND RELATED STUDIES

This chapter contains previous studies related to the design. It also has citations from other researchers which state observations that can be considered on the design.

SYRINGE PUMP

Syringe Pump is dedicated to intravenous dosage of little volume (up to 100 ml) medicaments (antibiotics, anesthetics, analgesics, chemotherapy reagents) with very high accuracy by using syringes. Syringe pump allows infusing medicaments at a constant or variable speed. Conventional syringe pumps mostly operate in stand-alone mode.

Stated by Markevicius and Navikas (2007), According to the statistics 39% errors are made while administering drugs, 10% errors are made in pharmacy and 38% errors are made when infusing drugs, 13% – due to other reasons. Moreover, very strict and reliable drug control must be ensured during infusion process, because if clinician does not notice that drugs are administered wrongly, in 98% cases these drugs will be infused to patient. Because of the reports and the statements above in which in this case, syringe pumps are critically important element – they have additional drug control mechanisms, so error probability is reduced. Combining human ability which takes decisions with computerized data processing, amount of errors can be substantially reduced.

Syringe pump safety features include an End of Travel Limit Switch that preserves precious contents and protects syringes from damage. "The syringe bracket prevents leakage and secures the plunger and syringe body to the pump" *(John, L., 2005).* This statement gives the researchers an idea to use limit switch in Programmable Syringe Flow Regulator. The limit switches give signal to the stepper motor to reset and stop once the syringe is empty. This is applied by placing two separate switches in which the distance is same as the length of the syringe.

Insulin injected with a mismatch between Insulin syringe and Insulin concentration in vial may have disastrous results and is one of the avoidable causes of hospitalization. These mistakes sometimes occur in Hospitals also. "Patients who are using 100 unit insulin and carry insulin with them, may accidentally get 2.5 times high amount of insulin dose due to hospital staff using patients insulin vial of 100 U but syringe is wrongly used as 40 U" *(Neff, 2008).*

STEPPER MOTOR

Stepper motors are widely used in various applications. They can be found in printers, disk drives, X-Y plotters, and many others which are required to move controlled objects to accurate positions within nominated time.

The single microprocessor controls the stepper motor by sending pulse sequences to the motor windings in response to control commands. Commands executed by the code in this application include: single step the motor in a

clockwise or counterclockwise direct ion (i. e. rotate the rotor through a certain number of degrees); run the motor continuously at one of four speeds in a clockwise or counterclockwise direction; and stop the motor (Kang and Qu, 1994).

This application describes the use of single microprocessor to control the speed, direction and rotation angle of a stepper motor. This single microprocessor controls the stepper motor by sending pulse sequences to the motor winding in response to control commands. Commands executed by the code in this application include: single step the motor in a clockwise or counterclockwise (i. e. rotate the rotor through a certain number of degrees); run the motor continuously at one of four speeds (25steps/second, 100steps/second, and 400steps/second) in a clockwise or counterclockwise direction; and stop the motor. This is a general purpose application for which a degree of adjustment or program ability is required to meet the needs of specific processor end their performances.

VISCOSITY

Viscosity is the main parameter that characterizes the flow of liquids in an industrial process, and its measurement provides information on the resistance to flow in tubes.

The syringe is similar to a piston pump. This type of pump has a piston inside a cylinder-like container in which it serves as the pusher for the contents of the liquid. This syringe plunger serves as the piston and its container serves as the cylinder. According to the book entitled Biological Process Engineering, "considering a piston accelerating within a cylinder, when it moves slowly, there is hardly any pressure increase in the liquid ahead of the piston. The entire column of the liquid moves within the tube at the same speed as the piston" *(Johnson, 1999).* Taking into account that the syringe is closely similar to a piston pump, it can be said that the statement above is applicable to syringe in which the speed of diffusion or flow rate of the liquid is dependent on the force applied in the plunger to the liquid. This nullifies the effect of viscosity of the liquid.

CHAPTER 3

DESIGN METHODOLOGY AND PROCEDURES

This chapter discusses the prototype design methodology used to develop the device and be able to achieve the objectives. The step by step procedures done on both hardware and software design are also essential to develop the prototype.

DESIGN METHODOLOGY

The prototype design methodology is patterned according to constructive research. Constructive research by definition mainly focuses on producing novel solutions to practically relevant problems. It gradually involves evaluation of the problem and a solution that fits the best based on the objectives or criteria being set. This kind of research is often used in Computer Science field of study.

As an identified problem which stated in the first paragraph of this chapter, knowing something about the past models and designs of the system is a must. Looking at the past researches would give some idea on how to approach the problem and supply necessary information needed to arrive at a given solution or conclusion. Therefore, conducting research is inevitable.

DESIGN PROCEDURES

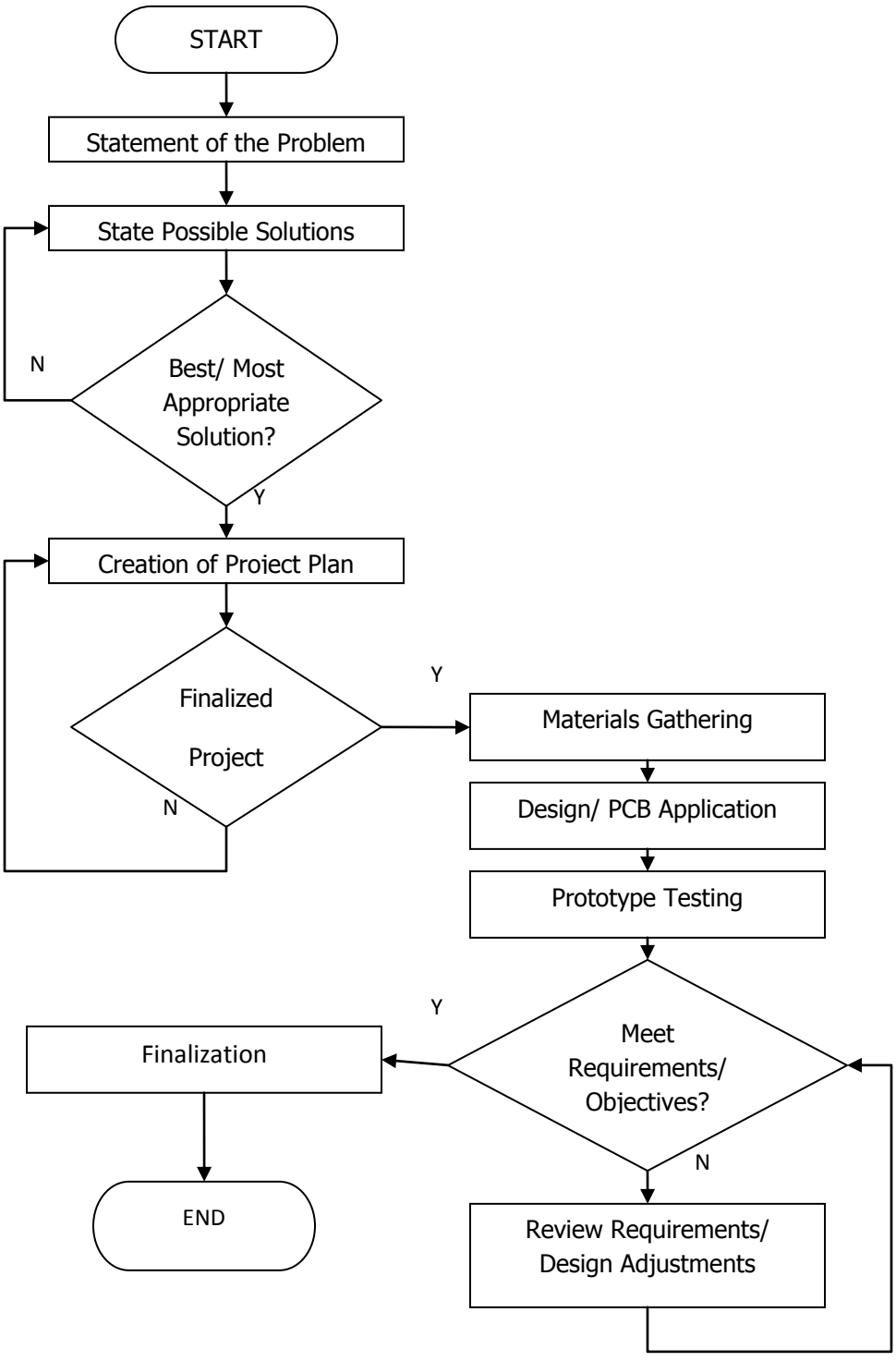

Figure 3.1 Design Procedures

In order to make the system developed, there are basic processes and tool that the proponents used in making the proposed system design. These processes are then taken step-by-step for guidelines in order to arrive at what is being set and expected. And those processes being used are the following:

1. **Materials Gathering**

   Since the project has already commercial implementations, it is assumed that all materials that will be used are already available in the local market. The best good option is to buy at the stores that sell in lowest prices but don't compromise the quality and can stand at a long period of time. Location can be a factor to the prices, so going to places like Quiapo specifically in Raon part where a lot of the needed semiconductor goods needed are available. For component parts, stores like Alexan are of good choice. Also visit some mechanical shops for helical screw.

2. **Design Creation/PCB Application**

   After completing the materials needed and finalized the created project plan, actual implementation and PCB application are the next steps. In these steps, all theories and ideas will be put into reality through actual making of a working design prototype. Also, a thing like programming of the microcontroller (PIC and PSOC) is done. See item d. PCB application of the hardware implementation

part of this chapter to see the actual PCB implementation of the project.

3. Prototype Testing

Since the prototype has been created, one is uncertain if the output of the prototype is correct or not even if it is already working. This can only be done by subjecting the designed system through series of test in determining if the output goes with the theories that have been applied and to what is the user has been expecting. This part also identifies the quality of work made and the coverage that it can cover as stated in the scope and delimitations in chapter 1. To see what are the testing methods being used, the next chapter discusses them.

HARDWARE DESIGN

a. Block Diagram

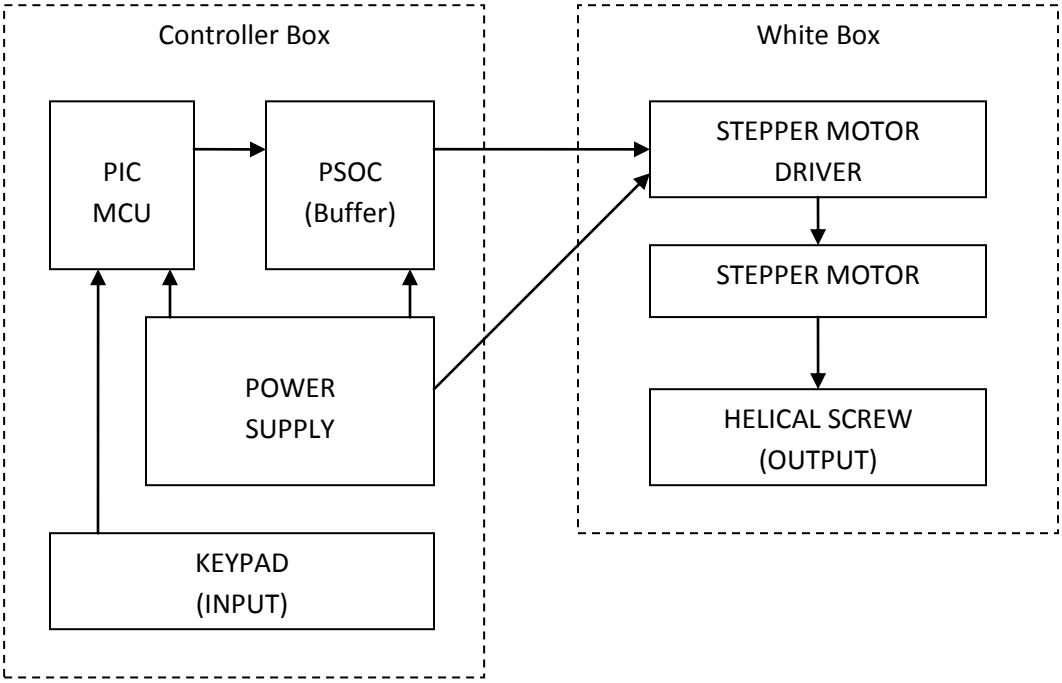

Figure 3.2 System Block Diagram

The Figure 3.2 from the previous page illustrates the block diagram of the system. The system is divided into main parts: a) Controller Box and b) White Box. The controller box which consists of the keypad, microcontroller (PIC and PSOC) and power supply serves as the main controller circuit, as the name implies, wherein the input is being processed. The user will be using the 0-9 digit keypad to enter flow rate which will be processed inside the PIC microcontroller. After sending the input, the PIC microcontroller will then make necessary computations needed in order to create an output. This output will be transferred first to the PSOC microcontroller in order to make the signal from the PIC

microcontroller gains strength. Another purpose of the PSOC microcontroller is to synchronize the stepper motor driver and PIC microcontroller due to clock timing issues between the two. The output from the PSOC microcontroller will serve as the input for the second part of the system which is the white box part. This white box serves as the output of the system that is composed of different parts such as stepper motor and its driver and the helical screw. The output from the PSOC microcontroller will be interpreted by the stepper motor driver for it to be able to make the stepper motor runs. The actions applied by the stepper motor will either turn the helical screw, where the syringe is attached, go back and forth.

b. Schematic Diagram

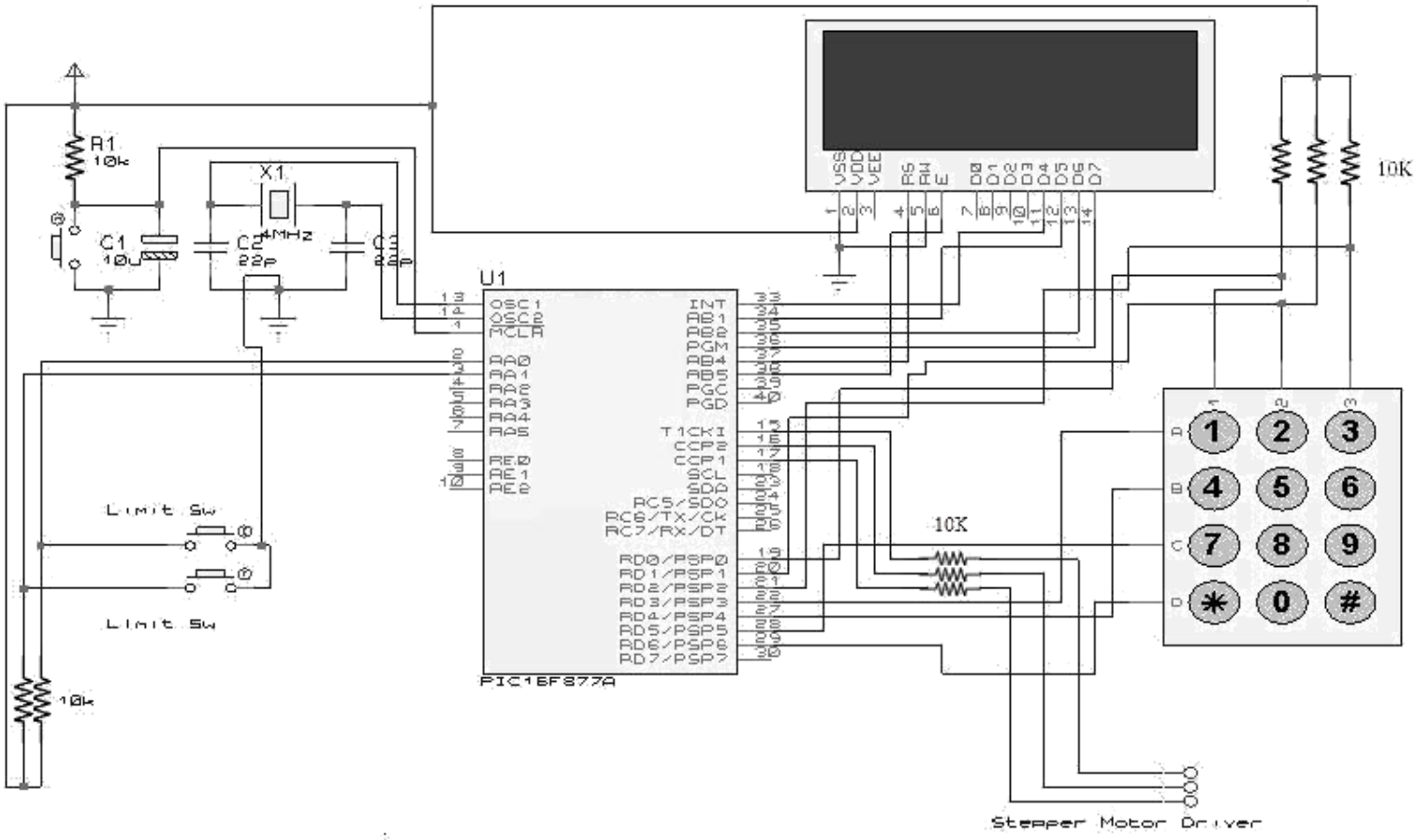

Figure 3.3 Microcontroller Interface Schematic Diagram

Figure 3.3 shows the schematic diagram of the circuit. This gives a detailed illustration of how each circuit component is to be interconnected to the other. Due to space constraints, the researchers subdivided the schematic diagram into three separate picture illustrations. The first is denoted by figure 3.3, the system main design circuit. This part houses the microcontroller, P1C16F877A, connected to other components like the LCD screen display and keypad.

The Figure 3.4 below gives the details about the interconnection of pins between the two main components contained in the figure illustration which are the stepper motor (circular shape) and its driver (rectangular shape). Then located on the driver's left side are the pins that must be connected to microcontroller through figure 3.3.

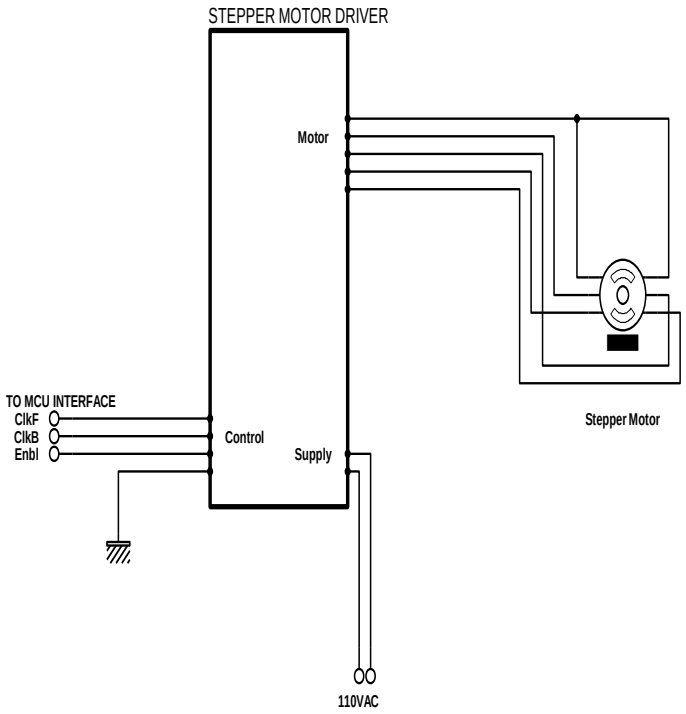

Figure 3.4 Stepper Motor Driver Schematic Diagram

Figure 3.5 illustrates the system's main power supply circuit diagram. It converts 22O V AC Voltage to 5 V DC Voltage for it to be usable to the circuit.

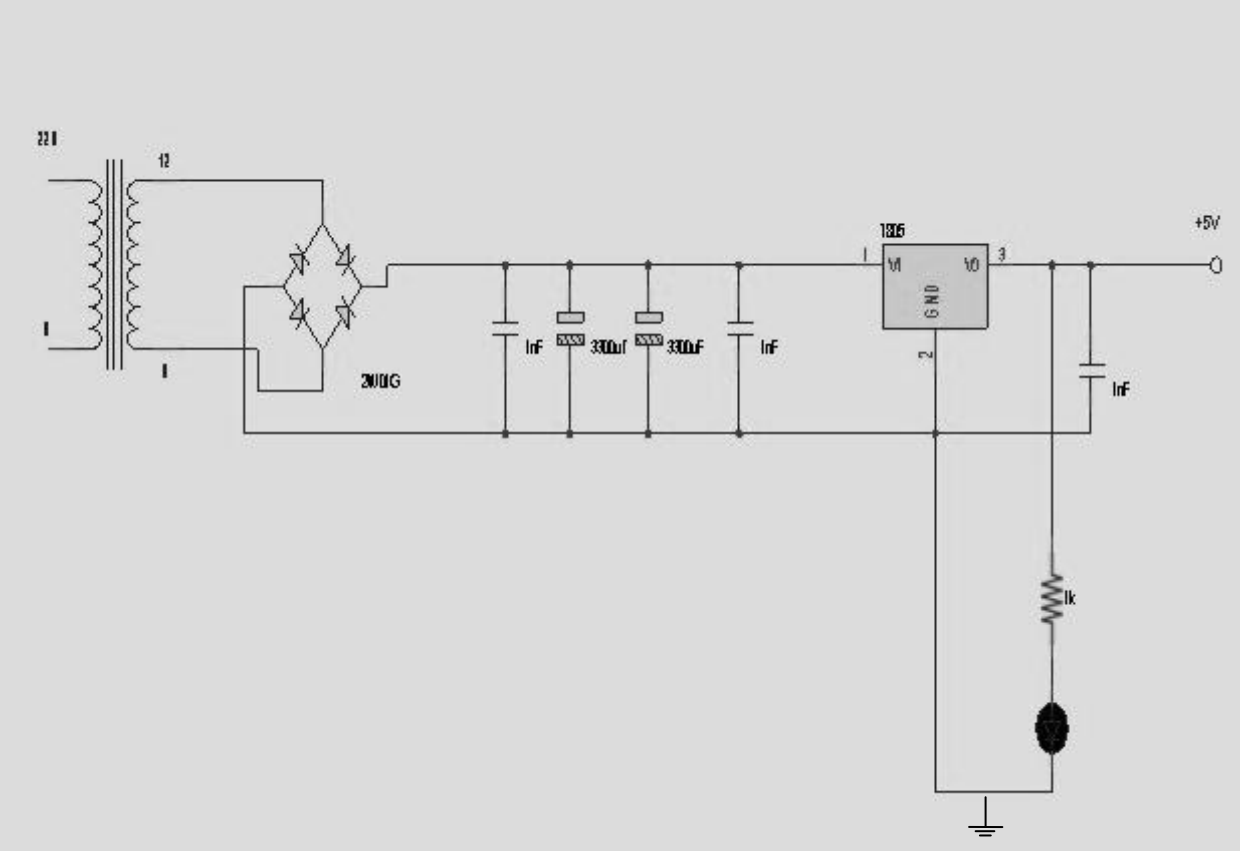

Figure 3.5 Power Supply Circuit Diagram

c. List of Materials

QUANTITY (IN PCS.)	MATERIAL
3	10K ohms resistor
1	LCD Monitor
1	PIC16F877A 28/40-pin 8-bit CMOS Flash Microcontroller
1	CY8C29466-24PXI 24 Pin PSOC Microcontroller
1	1-9 Keypad
1	Stepper Motor Driver
1	Stepper Motor
1	Helical screw
1	Linear Guide
1	Angular Screw
1	220V to 12V Step Down Transformer
3	1nF Capacitor
2	3300 uF Capacitor
1	1K ohms Resistor
4	Diode
1	LM7805 3-Terminal 1A Positive Voltage Regulator
1	Black Plastic Case
1	Wooden Box Case
1	Plastic Glass Cover
1	5 CC Syringe Injection
10 ft.	Wire

Table 3.1 List of Materials

Table 3.1 enumerates the different materials used in developing the Programmable Syringe Flow Regulator. Also included in the table are the quantities of the items used in the design.

SOFTWARE DESIGN

SYSTEM FLOWCHART

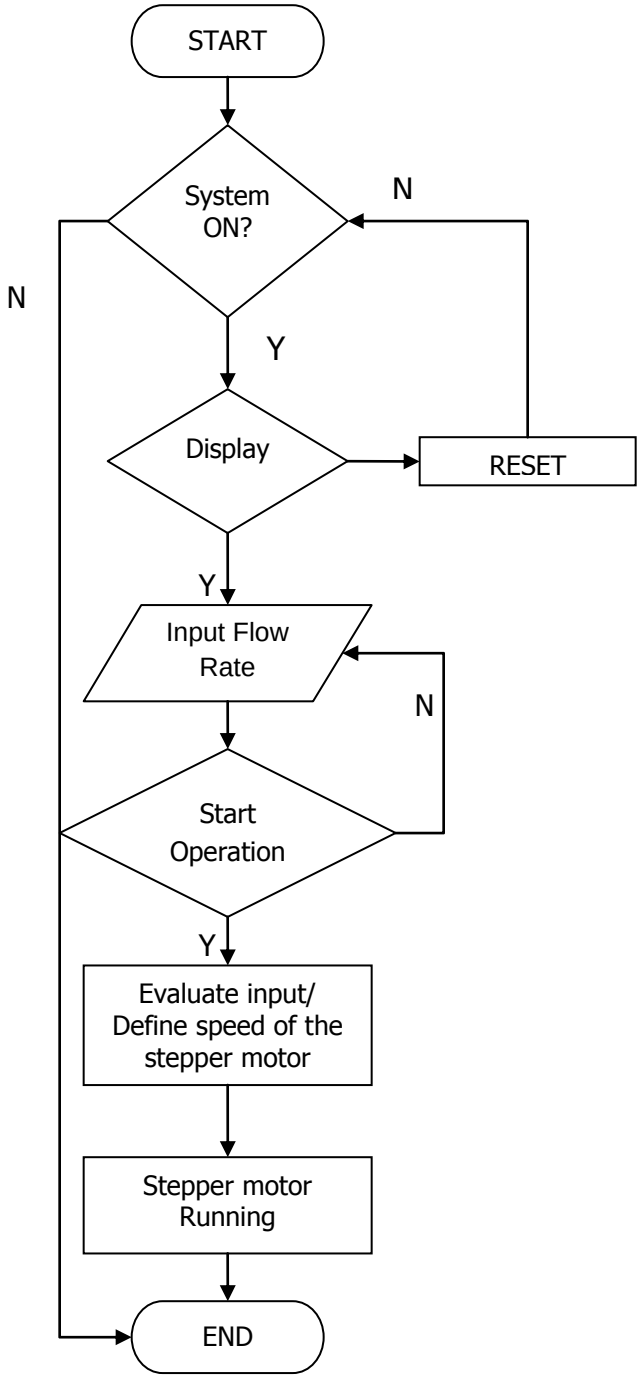

Figure 3.6 System Flow Chart

Figure 3.6 from the previous page, shows the overall design flow chart of the software. It also illustrates at the same time what are the steps that the system will take accordingly.

In brief summary, based on the figure shown, the system upon turning the power on a LCD screen will display a certain message about what flow rate that the user wanted. The user will decide whether the inputted flow rate is correct and want to start operation or not. In some cases, improper or incorrect inputs are entered but these can be solved by entering again the desired flow rate. After the system has received the input, it will be processed and analyzed by the program in the MCU. The output is expected after the MCU has successfully carried out the operation. This output varies accordingly to the input.

3. PROTOTYPE DEVELOPMENT

Primarily the source of input of the system is the keypad with number 0-9. Its inputs A, B, C and D which are bit representations of each corresponding number and will proceed to the MCU in ports psp03, psp04, psp05, psp06 accordingly as being shown in figure 3.3 of this chapter. This input will serve as a multiplier to the flow rate set at 0.04/cc. For example, if 5 is being pressed, the flow rate will be 5 x (0.04 cc/sec) and will result to 0.20 cc/sec as the flow rate. The flow rate will also be interpreted by the microprocessor for it to be

understood by the driver which will then late make the stepper motor rotate. The microprocessor being used is PIC which uses Assembly Language as its primary programming language. The only thing needed to do is to burn or write the program source code created to the microprocessor. The source code will be the one processing the input and make necessary computations needed to arrive to the expected output. Output is represented and shown in the LCD display, for the messages, and into the helical screw, which is the actual output of the system. The LCD display must be connected to the ports in the MCU as being shown in figure 3.3. The helical screw on the other hand must be connected to the driver. Moving aside, all of the most important components in the circuit are powered by using +5V dc through the power supply. Like the MCU and PSOC except the stepper motor driver which requires 110V AC voltage. (NOTE: Never plug the driver in a 220 V AC power.) .

Chapter 4

Testing, Presentation, and Interpretation of Results

This chapter is composed of several results to the tests done to the design in order to find out the performance of the syringe. The following are done in order to compare and evaluate the gathered results. With this, the following results may also be compared to the computed values.

The researchers performed different test in order to find out the change in speed and the length of the process of the syringe regulator. The syringe used was a 5 mL syringe, the syringe size that was referred to us to be used in this design. The chemical solutions used for the test are distilled drinking water (H_2O), ethyl alcohol (C_2H_5OH), coconut oil, glucose ($C_6H_{12}O_6$) and glycerol ($C_3H_8O_3$).

A. Time – Volume Accuracy Test

This test aims to know whether the time that the prototype would take in order to consume the desired volume of liquid is accurate or not.

Procedure for Time – Volume Accuracy Test

1. The syringe is filled with the sample liquid.
2. The desired flow rate is set.
3. A stopwatch is set to zero and starts when the plunger touches the end of the aluminum bar.

4. The researcher stops the time of the stopwatch as the syringe finishes filling 1ml.
5. Record the time.

Results for Time – Volume Accuracy Test:

The table below represents the results gathered after conducting the Time – Volume Accuracy Test. Each solution undergoes three trials of test to compare that the resulting time will be exactly or nearly the same as the computed one. The test shows that the time where the syringe finishes dispensing the solution is approximately the same as the results in the computed value. The ideal time is computed using the formula:

$$Computed\ result = \frac{1\ mL}{\frac{rate\ (mL)}{1\ min} \times \frac{1 min}{60 sec}}$$

All other unit will be cancelled except the second. Repeat this by substituting only the rate.

RATE (mL/min)	SAMPLE SOLUTIONS														
	WATER			GLUCOSE			GLYCEROL			ETHYL ALCOHOL			COCONUT OIL		
	TRIALS														
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
0.1	9:30	9:58	10:02	9:25	9:30	10:00	9:28	9:35	9:50	9:59	9:40	10:00	9:32	9:40	10:01
0.5	1:59	1:59	2:01	1:56	1:59	2:01	1:58	1:59	2:00	1:56	1:58	2:02	1:57	1:58	2:00
1	0:59	0:56	0:58	0:58	0:56	0:58	0:58	0:57	0:58	0:58	0:57	0:56	0:59	0:55	0:56
1.5	0:39	0:38	0:41	0:38	0:39	0:44	0:39	0:38	0:40:00	0:38	0:39	0:41	0:38	0:39	0:40
2	0:29	0:29	0:29	0:28	0:29	0:29	0:29	0:28	0:29	0:30	0:30	0:30	0:29	0:28	0:29

Table 4.1 Time – Volume Accuracy Test Results

Table 4.1 shows that the time 0.1mL finishes 1mL of solution ranges from 9:25 to 10:02. The time 0.5mL finishes 1mL of solution ranges from 1:56 to 2:01. The time 1.0mL finishes 1mL of solution ranges from 0:55 to 0:59. The time 1.5mL finishes 1mL of solution ranges from 0:38 to 0:44. The time 2.0mL finishes 1mL of solution ranges from 0:28 to 0:30. As the viscosity of the liquids is concerned, the time to fill-up 1mL with respect to the input volume is almost the same as the computed time but due to human error there are some fluctuations in the results.

COMPUTED RESULTS

$$\frac{1\ mL}{\frac{0.1\ mL}{1\ min} \times \frac{1\ min}{60\ sec}} = \frac{1\ mL}{0.00166667\ \frac{mL}{sec}} = 599.9988\ \textbf{sec} \approx \textbf{10}\ minutes$$

$$\frac{1\ mL}{\frac{0.5\ mL}{1\ min} \times \frac{1\ min}{60\ sec}} = \frac{1\ mL}{0.0083333\ \frac{mL}{sec}} = 120.00048\ \textbf{sec} \approx \textbf{2}\ minutes$$

$$\frac{1\ mL}{\frac{1.0\ mL}{1\ min} \times \frac{1\ min}{60\ sec}} = \frac{1\ mL}{0.0166667\ \frac{mL}{sec}} = 59.99988\ \textbf{sec} \approx \textbf{1}\ minute$$

$$\frac{1\ mL}{\frac{1.5\ mL}{1\ min} \times \frac{1\ min}{60\ sec}} = \frac{1\ mL}{0.02\ \frac{mL}{sec}} = 40\ sec$$

$$\frac{1\ mL}{\frac{2.0\ mL}{1\ min} \times \frac{1\ min}{60\ sec}} = \frac{1\ mL}{0.033333\ \frac{mL}{sec}} = 30\ sec$$

B. Input - Output Volume Comparison Test:

This test aims to compare if the output volume of liquid is the same as the programmed volume of liquid that should come out in one (1) minute.

Procedure for Input – Output Volume Comparison Test:

1. The syringe is filled with the sample liquid.
2. The desired flow rate is set.
3. A stopwatch is set to zero and starts when the plunger touches the end of the aluminum bar.
4. The researcher stops the time of the stopwatch until it reaches 1 minute.
5. The output is then measured through the use of the pipette.

Results for Input – Output Volume Comparison Test:

The table below represents the results gathered after conducting the Input – Output Volume Comparison Test. The results show that the volume being dispensed by the syringe is accurate and is nearly the same as the given volumetric rate.

RATE (mL/min)	SAMPLE SOLUTIONS													
	WATER (mL)	VISCOSITY LEVEL**												ETHYL ALCOHOL (mL)
		GLUCOSE (mL)				GLYCEROL (mL)				COCONUT OIL (mL)				
		3:3	3:2	3:1	Ave±SEM*	3:3	3:2	3:1	Ave±SEM*	3:3	3:2	3:1	Ave±SEM*	
0.1	0.09	0.09	0.08	0.08	0.0833333 ±0.003333	0.08	0.08	0.07	0.0766667 ±0.003333	0.09	0.09	0.1	0.0933333 ±0.003333	0.1
0.5	0.49	0.49	0.48	0.47	0.48 ±0.005774	0.48	0.48	0.48	0.48 ±0	0.49	0.49	0.49	0.49 ±0	0.48
1.0	0.97	0.99	0.99	0.98	0.9866667 ±0.003333	0.99	0.97	0.96	0.9733333 ±0.008819	0.97	0.97	0.98	0.9733333 ±0.003333	0.96
1.5	1.49	1.48	1.48	1.47	1.4766667 ±0.003333	1.49	1.48	1.47	1.48 ±0.005774	1.49	1.48	1.49	1.4866667 ±0.003333	1.45
2.0	1.9	1.99	1.98	1.96	1.9766667 ±0.008819	1.98	1.98	1.95	1.97 ±0.1	1.8	1.9	1.9	1.8666667 ±0.003333	1.7

**(volume/volume basis)
*(average; ±SEM)

Table 4.2 Input – Output Volume Comparison Test Results

Table 4.2 shows that for every solution, the researchers measured the output volume that came out in 1 minute with respect to the input rate. The output volume is measured using a pipette. Based on table 4.2, the output volume is almost the same as the input including the viscosity levels of glucose, glycerol and coconut oil. But due to some constraints, the ideal output cannot be achieved.

Formula for AVE±SEM:

$$\delta = \sqrt{\left(\frac{\Sigma\,(x - \bar{x})^2}{N}\right)}$$

$$SEM = \frac{\delta}{\sqrt{N}}$$

C. Cost Analysis

	Syringe Pump Products		
	SYR-1200	**NE-1000**	**Programmable Syringe Flow Regulator (PSFR)**
Features			
	• Timed Addition - Runs up to a 16-step program that adds multiple reagents to multiple reactors at user specified rates. • Program Loader - This program executes a user entered sequence of syringe pump commands. • Remote Control - Places every action of the syringe pump under the direct control of an attached PC. • Update Manager - Allows new programs to be uploaded into the syringe pump controller via Email or web site download.	• Infuses and withdraws • Selectable pump rate units: µl/hr, µl/min, ml/hr, ml/min. • Change pumping rate and direction while pumping. • Syringe purge mode will infuse or refill syringe at top speed to purge air from the line or to fill the syringe. • Audible buzzer can be programmed to alert when an alarm condition occurs or the pumping program completes. • Power failure mode restarts a pumping program interrupted by a power failure.	• User-friendly • Simple yet customize according to the end-user's preferences. • Easy to use. • Less expensive compared to low-end products available in the market. • Duplication is easy because of availability of materials in local market.
Specifications	• Dimensions:12"(H)x3.5"(W)x 12"(D) • Imprecision: 0.02% full stroke • Wetted Parts: Borosilicate glass and Teflon • Firmware: RS232 communications Automatic backlash compensation Absolute valve positioning	• Space Saving Chassis: Foot print size of only 5 3/4" x 8 3/4" • Easy-to-use keypad interface • Infusion rates from 0.73 µL/hr (1 cc syringe) to 2100 ml/hr (60 cc syringe) • Holds 1 Syringe up to 60 cc*	• Hold 1 syringe of 5 cc. • Infusion rate from 0.1 ml/min up to 9.9 ml/min • Programming Language: Assembly Language
Setup	1. Screw the syringe in the distribution valve. 2. Press the power button then press "Initialize". 3. Enter the correct syringe size.	1. Set syringe diameter 2. Set dispense rate 3. Set dispense volume 4. Press Start	1. Fill the syringe with liquid solution 2. Enter the flow rate in ml/min 3. Press * to start operation
Programmable	Yes	Yes	Yes
Price *(in php)*	**USD $ 2640 = Php 126,720**	**USD $ 830 = Php 39,840**	**Php 19,705.00**
Source	http://www.jkem.com/psp.html	http://www.syringepump.com/detailedfeatures.htm	

Table 4.3 Cost Analysis

Table 4.3 shows the comparison of the present devices available in the market as well as the Programmable Syringe Flow Regulator. It explains the differences of the devices in terms of their main features, specifications, and setup. It also proves that the Programmable Syringe Flow Regulator is much cheaper than the devices readily available in the market.

Chapter 5

CONCLUSION AND RECOMMENDATION

This chapter is composed of the researchers' conclusions after developing the Programmable Syringe Flow Regulator through thorough research and analysis. Consequently, the design has a room for improvements that can be enhanced by fellow and future researchers.

Conclusion

After the design testing, it is concluded that the Programmable Syringe Flow Regulator can dispense liquid in a constant rate regardless of its viscosity. And it is also concluded that:

1. The Programmable Syringe Flow Regulator can dispense the same actual volume in a given period of time based on table 4.2, the Input – Output volume comparison test, since the data show that there is a small difference between the expected output and the measured output.

2. The Programmable Syringe Flow Regulator is cheaper than those similar devices available in the market which is illustrated on figure 4.3, Cost Analysis. The cost is much cheaper compared to those in the market because it is made using local components. Component breakdown can be seen in Appendix A.

Recommendation

The following suggestions should help to make the device more convenient and useful:

1. A timer can be installed to measure the lapsed time when the liquid starts to flow.
2. Because of the bulkiness of the device, it should be smaller to lessen the space occupied in the laboratory and lighter to be portable in carrying.
3. The device can be more useful if it can hold different sizes of syringe.
4. A scheduler can be implemented to perform the task in a certain period of time.
5. Auto-filling of liquid in the syringe should be considered to avoid refilling the syringe over and over again.

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APPENDIX A

List of Materials and Price Listings

QUANTITY (IN PCS.)	MATERIAL	PRICE
3	10K ohms resistor	P1.00
1	LCD Monitor	P2,834.00
1	PIC16F877A 28/40-pin 8-bit CMOS Flash Microcontroller	P303.00
1	CY8C29466-24PXI 24 Pin PSOC Microcontroller	P405.00
1	1-9 Keypad	P1,650.00
1	Stepper Motor Driver	P10,500.00
1	Stepper Motor	P2,500.00
1	Helical screw	P250.00
1	Linear Guide	P200.00
1	Angular Screw	P200.00
1	220V to 12V Step Down Transformer	P38.00
3	1nF Capacitor	P48.00
2	3300 uF Capacitor	P382.00
1	1K ohms Resistor	P0.50
4	Diode	P1.00
1	LM7805 3-Terminal 1A Positive Voltage Regulator	P51.00
1	Black Plastic Case	P150.00
1	Wooden Box Case	P100.00
1	Plastic Glass Cover	P50.00
1	5 CC Syringe Injection	P17.00
10 ft.	Wire	P25.00
	TOTAL:	**P19,705.00**

APPENDIX B

Data Sheets

MICROCHIP

PIC16F87X

28/40-pin 8-Bit CMOS FLASH Microcontrollers

Devices Included in this Data Sheet:

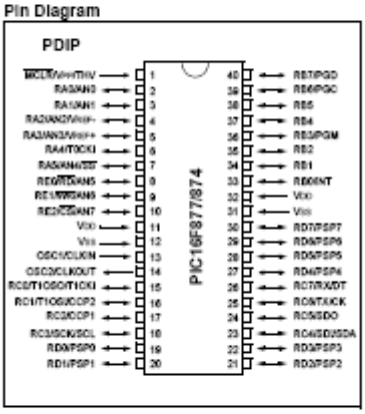
- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and
  Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram

PDIP



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

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Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

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FAIRCHILD
SEMICONDUCTOR®

www.fairchildsemi.com

MC78XX/LM78XX/MC78XXA

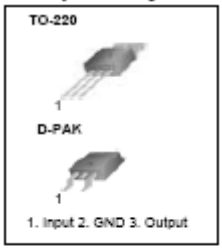
3-Terminal 1A Positive Voltage Regulator

Features

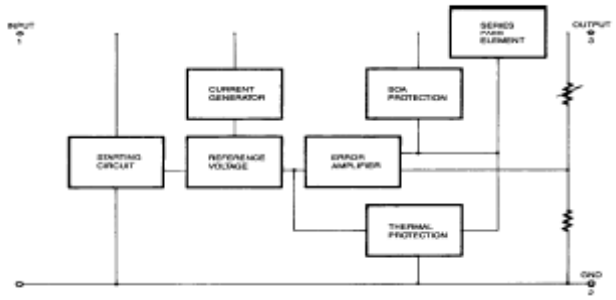
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The MC78XX/LM78XX/MC78XXA series of three terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



Internal Block Digram



Rev. 1.0.1

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Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V to 18V) (for V_O = 24V)	V_I V_I	35 40	V V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	°C/W
Operating Temperature Range	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Electrical Characteristics (MC7805/LM7805)

(Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I = 10V, C_I= 0.33μF, C_O= 0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7805/LM7805			Unit
				Min.	Typ.	Max.	
Output Voltage	V_O	T_J =+25 °C		4.8	5.0	5.2	V
		5.0mA ≤ I_O ≤ 1.0A, P_O ≤ 15W V_I = 7V to 20V		4.75	5.0	5.25	
Line Regulation (Note1)	Regline	T_J=+25 °C	V_O = 7V to 25V	-	4.0	100	mV
			V_I = 8V to 12V	-	1.6	50	
Load Regulation (Note1)	Regload	T_J=+25 °C	I_O = 5.0mA to1.5A	-	9	100	mV
			I_O =250mA to 750mA	-	4	50	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.03	0.5	mA
		V_I= 7V to 25V		-	0.3	1.3	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O= 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A=+25 °C		-	42	-	μV/Vo
Ripple Rejection	RR	f = 120Hz V_O = 8V to 18V		62	73	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	15	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A =+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

1N4004 and 1N4007 are Preferred Devices

Axial Lead Standard Recovery Rectifiers

This data sheet provides information on subminiature size, axial lead mounted rectifiers for general−purpose low−power applications.

Mechanical Characteristics

- Case: Epoxy, Molded
- Weight: 0.4 gram (approximately)
- Finish: All External Surfaces Corrosion Resistant and Terminal Leads are Readily Solderable
- Lead and Mounting Surface Temperature for Soldering Purposes: 220°C Max. for 10 Seconds, 1/16" from case
- Shipped in plastic bags, 1000 per bag.
- Available Tape and Reeled, 5000 per reel, by adding a "RL" suffix to the part number
- Available in Fan−Fold Packaging, 3000 per box, by adding a "FF" suffix to the part number
- Polarity: Cathode Indicated by Polarity Band
- Marking: 1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

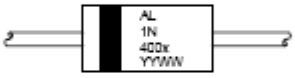
ON Semiconductor™

http://onsemi.com

LEAD MOUNTED RECTIFIERS
50−1000 VOLTS
DIFFUSED JUNCTION

CASE 59−03
AXIAL LEAD
PLASTIC

MARKING DIAGRAM



AL = Assembly Location
1N400x = Device Number
x = 1, 2, 3, 4, 5, 6 or 7
YY = Year
WW = Work Week

MAXIMUM RATINGS

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
*Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	Volts
*Non−Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz)	V_{RSM}	60	120	240	480	720	1000	1200	Volts
*RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	Volts
*Average Rectified Forward Current (single phase, resistive load, 60 Hz, T_A = 75°C)	I_O	1.0							Amp
*Non−Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	30 (for 1 cycle)							Amp
Operating and Storage Junction Temperature Range	T_J T_{stg}	−65 to +175							°C

*Indicates JEDEC Registered Data

ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

Preferred devices are recommended choices for future use and best overall value.

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ELECTRICAL CHARACTERISTICS*

Rating	Symbol	Typ	Max	Unit
Maximum Instantaneous Forward Voltage Drop (I_F = 1.0 Amp, T_J = 25°C)	v_F	0.93	1.1	Volts
Maximum Full−Cycle Average Forward Voltage Drop (I_O = 1.0 Amp, T_L = 75°C, 1 Inch leads)	$V_{F(AV)}$	–	0.8	Volts
Maximum Reverse Current (rated dc voltage) (T_J = 25°C) (T_J = 100°C)	I_R	0.05 1.0	10 50	μA
Maximum Full−Cycle Average Reverse Current (I_O = 1.0 Amp, T_L = 75°C, 1 Inch leads)	$I_{R(AV)}$	–	30	μA

*Indicates JEDEC Registered Data

ORDERING & SHIPPING INFORMATION

Device	Package	Shipping
1N4001	Axial Lead	1000 Units/Bag
1N4001FF	Axial Lead	3000 Units/Box
1N4001RL	Axial Lead	5000/Tape & Reel
1N4002	Axial Lead	1000 Units/Bag
1N4002FF	Axial Lead	3000 Units/Box
1N4002RL	Axial Lead	5000/Tape & Reel
1N4003	Axial Lead	1000 Units/Bag
1N4003FF	Axial Lead	3000 Units/Box
1N4003RL	Axial Lead	5000/Tape & Reel
1N4004	Axial Lead	1000 Units/Bag
1N4004FF	Axial Lead	3000 Units/Box
1N4004RL	Axial Lead	5000/Tape & Reel
1N4005	Axial Lead	1000 Units/Bag
1N4005FF	Axial Lead	3000 Units/Box
1N4005RL	Axial Lead	5000/Tape & Reel
1N4006	Axial Lead	1000 Units/Bag
1N4006FF	Axial Lead	3000 Units/Box
1N4006RL	Axial Lead	5000/Tape & Reel
1N4007	Axial Lead	1000 Units/Bag
1N4007FF	Axial Lead	3000 Units/Box
1N4007RL	Axial Lead	5000/Tape & Reel

1N5400 thru 1N5408

1N5404 and 1N5408 are Preferred Devices

Axial-Lead Standard Recovery Rectifiers

Lead mounted standard recovery rectifiers are designed for use in power supplies and other applications having need of a device with the following features:

- High Current to Small Size
- High Surge Current Capability
- Low Forward Voltage Drop
- Void-Free Economical Plastic Package
- Available in Volume Quantities
- Plastic Meets UL 94V–0 for Flammability

Mechanical Characteristics

- Case: Epoxy, Molded
- Weight: 1.1 gram (approximately)
- Finish: All External Surfaces Corrosion Resistant and Terminal Leads are Readily Solderable
- Lead and Mounting Surface Temperature for Soldering Purposes: 220°C Max. for 10 Seconds, 1/16" from case
- Polarity: Cathode Indicated by Polarity Band
- Marking: 1N5400, 1N5401, 1N5402, 1N5404, 1N5406, 1N5407, 1N5408

MAXIMUM RATINGS

Please See the Table on the Following Page

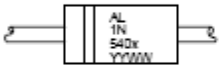
ON Semiconductor™

http://onsemi.com

STANDARD RECOVERY RECTIFIERS 50–1000 VOLTS 3.0 AMPERES

AXIAL LEAD CASE 267–05 STYLE 1

MARKING DIAGRAM



AL = Assembly Location
1N540x = Device Number
x = 0, 1, 2, 4, 6, 7 or 8
YY = Year
WW = Work Week

ORDERING INFORMATION

Device	Package	Shipping
1N5400	Axial Lead	500 Units/Box
1N5400RL	Axial Lead	1200/Tape & Reel
1N5401	Axial Lead	500 Units/Box
1N5401RL	Axial Lead	1200/Tape & Reel
1N5402	Axial Lead	500 Units/Box
1N5402RL	Axial Lead	1200/Tape & Reel
1N5404	Axial Lead	500 Units/Box
1N5404RL	Axial Lead	1200/Tape & Reel
1N5406	Axial Lead	500 Units/Box
1N5406RL	Axial Lead	1200/Tape & Reel
1N5407	Axial Lead	500 Units/Box
1N5407RL	Axial Lead	1200/Tape & Reel
1N5408	Axial Lead	500 Units/Box
1N5408RL	Axial Lead	1200/Tape & Reel

Preferred devices are recommended choices for future use and best overall value.

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MAXIMUM RATINGS

Rating	Symbol	1N5400	1N5401	1N5402	1N5404	1N5406	1N5407	1N5408	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	Volts
Non−repetitive Peak Reverse Voltage	V_{RSM}	100	200	300	525	800	1000	1200	Volts
Average Rectified Forward Current (Single Phase Resistive Load, 1/2" Leads, T_L = 105°C)	I_O	3.0							Amp
Non−repetitive Peak Surge Current (Surge Applied at Rated Load Conditions)	I_{FSM}	200 (one cycle)							Amp
Operating and Storage Junction Temperature Range	T_J T_{stg}	−65 to +170 −65 to +175							°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Unit
Thermal Resistance, Junction to Ambient (PC Board Mount, 1/2" Leads)	$R_{\theta JA}$	53	°C/W

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Forward Voltage (I_F = 3.0 Amp, T_A = 25°C)	V_F	−	−	1.0	Volts
Reverse Current (Rated dc Voltage) T_A = 25°C T_A = 150°C	I_R	 − −	 − −	 10 100	μA

Ratings at 25°C ambient temperature unless otherwise specified.
60 Hz resistive or inductive loads.
For capacitive load, derate current by 20%.

NOTE 1 — AMBIENT MOUNTING DATA

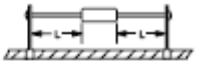
Data shown for thermal resistance junction−to−ambient ($R_{\theta JA}$) for the mountings shown is to be used as typical guideline values for preliminary engineering or in case the tie point temperature cannot be measured.

TYPICAL VALUES FOR $R_{\theta JA}$ IN STILL AIR

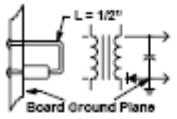
Mounting Method	Lead Length, L (IN)				$R_{\theta JA}$
	1/8	1/4	1/2	3/4	
1	50	51	53	55	°C/W
2	58	59	61	63	°C/W
3	28				°C/W

MOUNTING METHOD 1
P.C. Board Where Available Copper Surface area is small

MOUNTING METHOD 2
Vector Push−In Terminals T−28



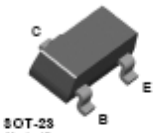
MOUNTING METHOD 3
P.C. Board with 1−1/2" x 1−1/2" Copper Surface



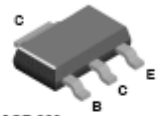
FAIRCHILD
SEMICONDUCTOR™

PN2222A MMBT2222A PZT2222A

TO-92



SOT-23
Mark: 1P



SOT-223

NPN General Purpose Amplifier

This device is for use as a medium power amplifier and switch requiring collector currents up to 500 mA. Sourced from Process 19.

Absolute Maximum Ratings* T_A = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	75	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current - Continuous	1.0	A
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics T_A = 25°C unless otherwise noted

Symbol	Characteristic	Max			Units
		PN2222A	*MMBT2222A	**PZT2222A	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	1,000 8.0	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3			°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	125	°C/W

*Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

**Device mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm; mounting pad for the collector lead min. 6 cm^2.

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NPN General Purpose Amplifier
(continued)

Electrical Characteristics
T_A = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage*	I_C = 10 mA, I_B = 0	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 10 µA, I_E = 0	75		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 µA, I_C = 0	6.0		V
I_{CEX}	Collector Cutoff Current	V_{CE} = 60 V, $V_{EB(OFF)}$ = 3.0 V		10	nA
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V, I_E = 0 V_{CB} = 60 V, I_E = 0, T_A = 150°C		0.01 10	µA µA
I_{EBO}	Emitter Cutoff Current	V_{EB} = 3.0 V, I_C = 0		10	nA
I_{BL}	Base Cutoff Current	V_{CE} = 60 V, $V_{EB(OFF)}$ = 3.0 V		20	nA
ON CHARACTERISTICS					
h_{FE}	DC Current Gain	I_C = 0.1 mA, V_{CE} = 10 V I_C = 1.0 mA, V_{CE} = 10 V I_C = 10 mA, V_{CE} = 10 V I_C = 10 mA, V_{CE} = 10 V, T_A = -55°C I_C = 150 mA, V_{CE} = 10 V* I_C = 150 mA, V_{CE} = 1.0 V* I_C = 500 mA, V_{CE} = 10 V*	35 50 75 35 100 50 40	 300 	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage*	I_C = 150 mA, I_B = 15 mA I_C = 500 mA, I_B = 50 mA		0.3 1.0	V V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage*	I_C = 150 mA, I_B = 15 mA I_C = 500 mA, I_B = 50 mA	0.6	1.2 2.0	V V
SMALL SIGNAL CHARACTERISTICS					
f_T	Current Gain - Bandwidth Product	I_C= 20 mA, V_{CE}= 20 V, f= 100 MHz	300		MHz
C_{obo}	Output Capacitance	V_{CB} = 10 V, I_E = 0, f = 100 kHz		8.0	pF
C_{ibo}	Input Capacitance	V_{EB} = 0.5 V, I_C = 0, f = 100 kHz		25	pF
rb'Cc	Collector Base Time Constant	I_C= 20 mA, V_{CE}= 20 V, f= 31.8 MHz		150	pS
NF	Noise Figure	I_C = 100 µA, V_{CE} = 10 V, R_S = 1.0 kΩ, f = 1.0 kHz		4.0	dB
Re(h_{ie})	Real Part of Common-Emitter High Frequency Input Impedance	I_C = 20 mA, V_{CE} = 20 V, f = 300 MHz		60	Ω
SWITCHING CHARACTERISTICS					
t_d	Delay Time	V_{CC} = 30 V, $V_{EB(OFF)}$ = 0.5 V,		10	ns
t_r	Rise Time	I_C = 150 mA, I_{B1} = 15 mA		25	ns
t_s	Storage Time	V_{CC} = 30 V, I_C = 150 mA,		225	ns
t_f	Fall Time	I_{B1} = I_{B2} = 15 mA		60	ns

*Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%

Spice Model

NPN (Is=14.34f Xti=3 Eg=1.11 Vaf=74.03 Bf=255.9 Ne=1.307 Ise=14.34f Ikf=.2847 Xtb=1.5 Br=6.092 Nc=2 Isc=0 Ikr=0 Rc=1 Cjc=7.306p Mjc=.3416 Vjc=.75 Fc=.5 Cje=22.01p Mje=.377 Vje=.75 Tr=46.91n Tf=411.1p Itf=.6 Vtf=1.7 Xtf=3 Rb=10)

NAN YA PLASTICS CORP. ELEC. MATERIALS DIV. LCD DEPARTMENT	SPECIFICATION	SPEC. NO. : LM069-0 DATE : DEC.01.1997 SHEET NO. : 1/19

U.S. MARKETING ARM:

MARK PRODUCTS CORPORATION
800 N. EDGEWOOD AVENUE
WOOD DALE, IL 60191
TEL: 630-787-9089
FAX: 630-787-9015

SPECIFICATION OF
20x4 LCD MODULE
PRODUCT NO.: LM_74_069_

SPEC. NO.: LM069-0

APPROVED BY

EDITED ON : DEC.01.1997

SALES MANAGER	DESIGN MANAGER	PERSON IN CHARGE

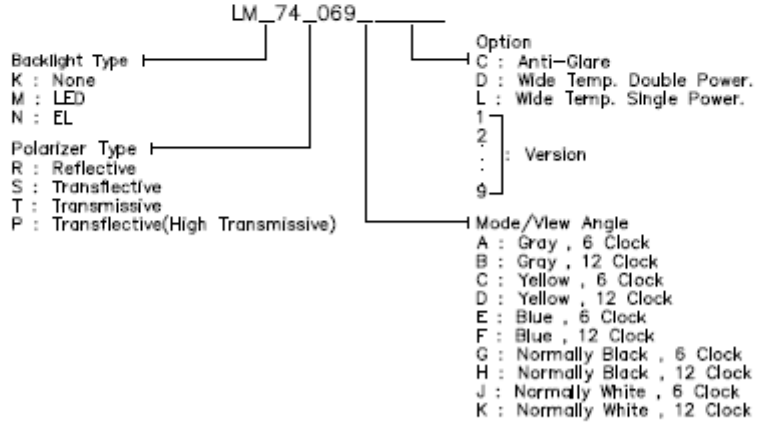
REV/DATE	RO/ 12.01.97'					APP	CHK	BY

NAN YA PLASTICS CORP. ELEC. MATERIALS DIV. LCD DEPARTMENT	SPECIFICATION	SPEC. NO. : LM069-0 DATE : DEC.01.1997 SHEET NO. : 2/19

1. MECHANICAL DATA

(1) Product No.	LM_74_069_	
(2) Module Size	77.0 (W)mm x 47.0 (H)mm x MAX10.0 (D)mm (W/O,EL B.L.)	
(3) Dot Size	0.42 (W)mm x 0.46 (H)mm	
(4) Dot Pitch	0.47 (W)mm x 0.51 (H)mm	
(5) Number of Characters	20 (W) x 4 (H)Characters	
(6) Character Format	5 (W) x 8 (H)Dots	
(7) Duty	1/16	
(8) LCD Display Mode	STN: ☐ Gray Mode	☐ Yellow Mode ☐ Blue Mode
	FSTN: ☐ Black and White(Normal White/Positive Image)	
	☐ Black and White(Normal Black/Negative Image)	
	Rear Polarizer: ☐ Reflective	☐ Transflective ☐ Transmissive
(9) Viewing Direction	☐ 6 O'clock	☐ 12 O'clock ☐ ____O'clock
(10) Backlight	☐ W/O	☐ LED ☐ EL
(11) Weight	W/O B/L: 33.8 g	

Note :



REV/DATE	R0/ 12.01.97'					APP	CHK	BY

APPENDIX C

Program Listings

```
Device 16F877A
Declare XTAL = 4
Declare LCD_TYPE 0
Declare LCD_DTPIN PORTB.0
Declare LCD_ENPIN PORTB.5
Declare LCD_RSPIN PORTB.4
Declare LCD_INTERFACE 4
Declare LCD_LINES 2
Print At 1,1, "Initializing...."
Print At 2,1, "Standby "
DelayMS 400
ADCON1 = 7 ' Set PORTA DIGITAL
OPTION_REG.7 = 0 ' DISABLE INTERNAL PULLUPS
ALL_DIGITAL = true
TRISA=%000011
TRISC=%00000000
TRISD=%00000111
TRISB=%00000000
TRISE=%000
PORTC = 0
Symbol BUZZ = PORTB.7
Symbol ENBL = PORTC.0
Symbol MOTOUT = PORTC.1
Symbol MOTHOME = PORTC.2
Symbol SWOUT = PORTA.0
Symbol SWHOME = PORTA.1
DelayMS 500
Dim Scar1 As Byte
Dim VALID As Byte
Dim Numeric As Byte
Dim POINTS As Byte
Dim ONES As Byte
Dim INTERVAL As Byte
Dim SCARINTERVAL As Word
Dim SCARRATE As Byte
Dim TIMEDELAY As Word
Dim RATE As Byte

GoSub INITMECH

;-------------------------------------------------
-------------------
; Main Program
;-------------------------------------------------
-------------------
MAIN:
Print At 1,1, " Auto Syringe "
Print At 2,1, " [*]Start"
DelayMS 400
GoSub KEYPAD
If Numeric = 11 Then GoSub BEEP : GoTo
BEGIN
Print At 1,1, " Auto Syringe "
Print At 2,1, " [ ]Start"
DelayMS 400
GoSub KEYPAD
If Numeric = 11 Then GoSub BEEP : GoTo
BEGIN
GoTo MAIN
;-------------------------------------------------
; START PROCESS
;-------------------------------------------------
BEGIN:
GoSub UNISET_THREE
If POINTS = 0 Then
If ONES = 0 Then GoTo BEGIN
End If
INTERVAL = 0
Here:
If POINTS = 0 Then GoTo Pnext
POINTS = POINTS - 1
INTERVAL = INTERVAL + 1
GoTo Here
Pnext:
If ONES = 0 Then GoTo PROCEED
ONES = ONES - 1
POINTS = 10
GoTo Here


PROCEED:
TIMEDELAY = 1160 / INTERVAL
' Print At 1,1, " "
' Print At 1,1, "time:",dec5 timedelay
' delayms 5000
' goto main
Z1:
Low ENBL
Low MOTOUT
```

```
Low MOTHOME
Low MOTHOME
Z1a:
If SWOUT = 0 Then GoTo FINISH
High MOTOUT
GoSub DELAY2
Low MOTOUT
GoSub DELAY2
GoTo Z1a

FINISH:
High ENBL
Low MOTHOME
Low MOTOUT
GoSub INITMECH
GoTo MAIN

UNISET_THREE:
ONES = 0
POINTS = 0
Print At 1,1, " Auto Syringe "
Print At 2, 1, "ENTER[0.0]mL/Min"
THER0:
Print $FE, $0F
Cursor 2 , 7
GoSub KEYPAD
If Numeric= 11 Then GoTo TCANCEL
If Numeric= 12 Then GoTo
UNISET_THREE
If Numeric = 30 Then GoTo THER0
ONES = Numeric
Print At 2,7, Dec ONES
GoSub BEEP
THER1:
Print $FE, $0F
Cursor 2 , 9
GoSub KEYPAD
If Numeric= 11 Then GoTo TCANCEL
If Numeric= 12 Then GoTo
UNISET_THREE
If Numeric = 30 Then GoTo THER1
POINTS = Numeric
Print At 2,9, Dec POINTS
GoSub BEEP
Print $FE, $0C
GoSub BEEP
Return
TCANCEL:
Print $FE, $0C
VALID = 0
Return

;-----------------------------------------------
; SPEED Rate
;-----------------------------------------------
DELAY1:
DelayMS 1155
Return
DELAY2:
DelayMS TIMEDELAY
Return

;-----------------------------------------------
; Initialized
;-----------------------------------------------
INITMECH:
If SWHOME = 0 Then GoTo Q1
Low ENBL
Low MOTOUT
Low MOTHOME
F1:
If SWHOME = 0 Then GoTo Q1
High MOTHOME
DelayUS 400
Low MOTHOME
DelayUS 400
GoTo F1
Q1:
High ENBL
Low MOTHOME
Low MOTOUT
Return
;-----------------------------------------------
; BEEP
;-----------------------------------------------
BEEP:
High BUZZ
DelayMS 300
Low BUZZ
DelayMS 100
Return
;-----------------------------------------------
```

```
--------------------
; Keypad Scanning
;--------------------------------------------------
--------------------
KEYPAD:
Numeric = 30
PORTD=%01110000
DelayMS 1
If PORTD.0=0 Then GoTo one
If PORTD.1=0 Then GoTo two
If PORTD.2=0 Then GoTo three
PORTD=%01101000
DelayMS 1
If PORTD.0=0 Then GoTo four
If PORTD.1=0 Then GoTo five
If PORTD.2=0 Then GoTo six
PORTD=%01011000
DelayMS 1
If PORTD.0=0 Then GoTo seven
If PORTD.1=0 Then GoTo eight
If PORTD.2=0 Then GoTo nine
PORTD=%00111000
DelayMS 1
If PORTD.0=0 Then GoTo aste
If PORTD.1=0 Then GoTo zero
If PORTD.2=0 Then GoTo pound
PORTD=0
Return
one:
If PORTD.0=0 Then GoTo one
Numeric = 1
Return
two:
If PORTD.1=0 Then GoTo two
Numeric = 2
Return
three:
If PORTD.2=0 Then GoTo three
Numeric = 3
Return
four:
If PORTD.0=0 Then GoTo four
Numeric = 4
Return
five:
If PORTD.1=0 Then GoTo five
Numeric = 5
Return
six:
If PORTD.2=0 Then GoTo six
Numeric = 6
Return
seven:
If PORTD.0=0 Then GoTo seven
Numeric = 7
Return
eight:
If PORTD.1=0 Then GoTo eight
Numeric = 8
Return
nine:
If PORTD.2=0 Then GoTo nine
Numeric = 9
Return
aste:
If PORTD.0=0 Then GoTo aste
Numeric = 11
Return
pound:
If PORTD.2=0 Then GoTo pound
Numeric = 12
Return
zero:
If PORTD.1=0 Then GoTo zero
Numeric = 0
Return
End
```

APPENDIX D

User's Manual

Programmable Syringe Flow Regulator

User's Manual

SAFETY GUIDELINES:

1. Avoid shaking or dropping the device.
2. Check first if the cord labelled with 110 is connected to a transformer before plugging.
3. Avoid the stepper motor and the main controller (black box) in getting wet.
4. Be careful in attaching the syringe to the holder to avoid accident.
5. Make sure that there is a container to catch the liquid coming out of the syringe during process.
6. Avoid excessive pulling of the main controller from the output brown box so that the wires would not be damaged.

HOW TO USE:

1. Connect the plug according to its corresponding power requirements. 220V and 110V for the main controller [9] and syringe [10] respectively.
2. Press the power button [2] to turn on the system.

   NOTE: *See to it that the syringe is already filled with liquid.*

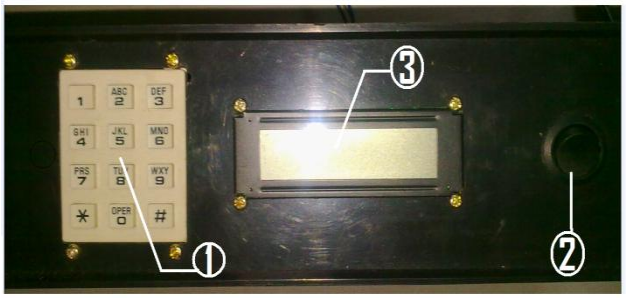
3. After doing step 2, press asterisk (*) to direct the display [3] to the flow rate input display.
4. At the flow rate input display, enter the desired flow rate from 0.1 to 9.9 ml/min. It will automatically start upon finishing the input.

   NOTE: *Sound coming from the stepper motor [4] can be heard when it is starting its operation.*

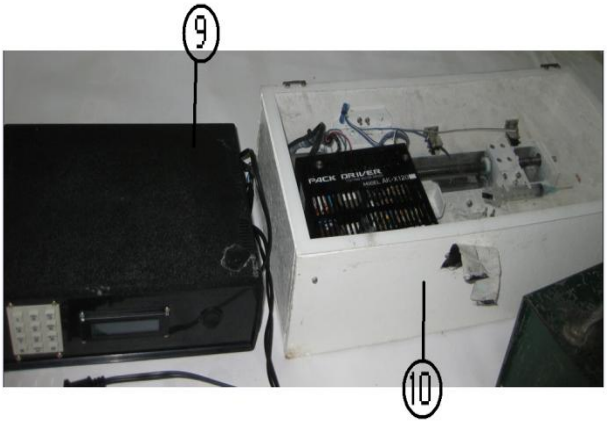
5. Wait until the contents of the syringe [6] completely have been diffused. Press Reset buttons [7] if you want to stop the operations.
6. Turn the power button off and unplug if not in use.

DEVICE COMPONENTS

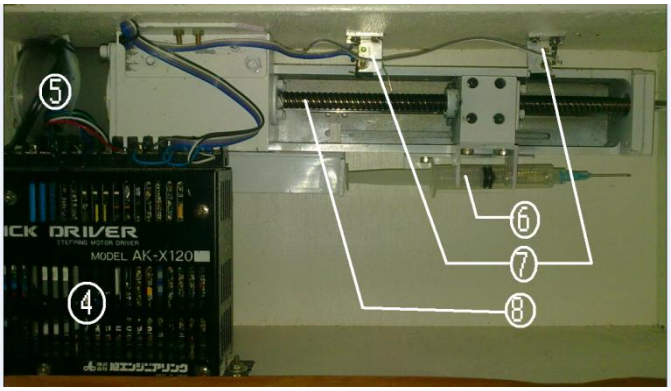
MAIN CONTROLLER: *(black box)*



TOP VIEW:



SYRINGE BOX: *(brown box)*



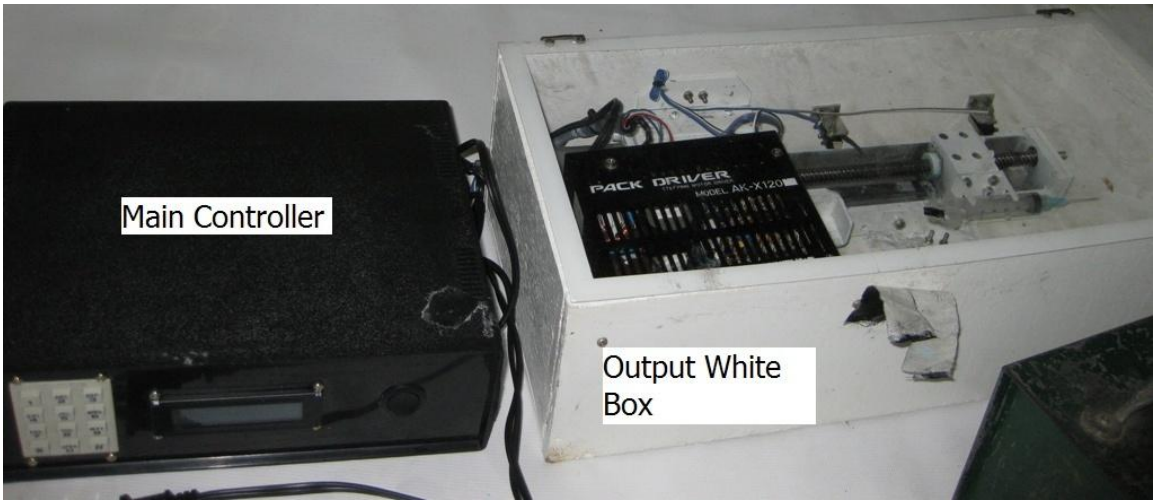
1. Numeric Keypads 2. Power Button (ON/OFF) 3. LCD Display 4. Stepper Motor Driver 5. Stepper Motor	6. Syringe Injection 7. Limit Buttons / Reset 8. Helical Screw 9. Main Controller *(black box)* 10. Syringe Box *(brown box)*

APPENDIX E

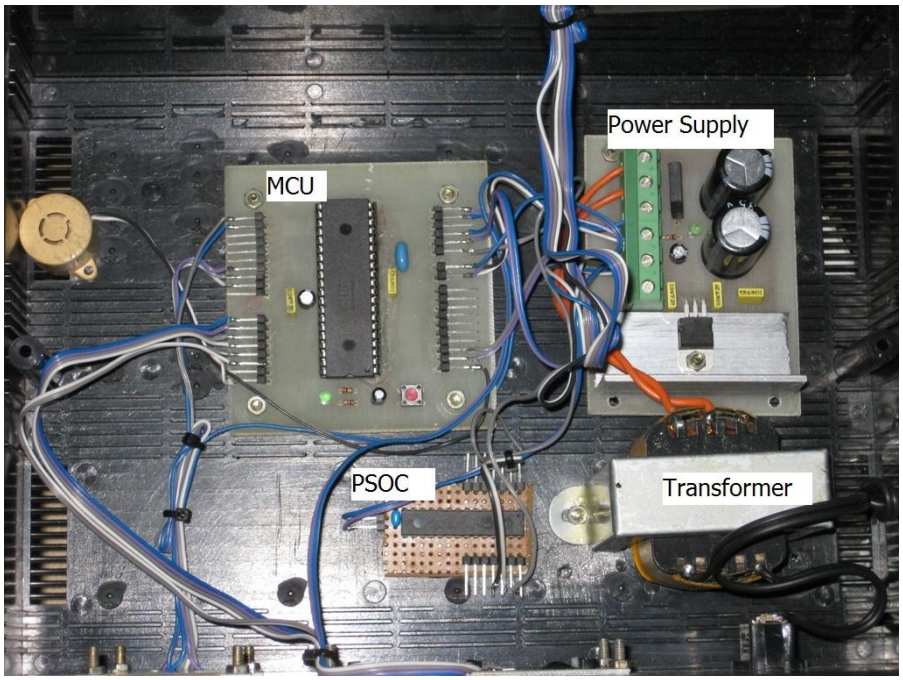
Device Components

DEVICE COMPONENTS:

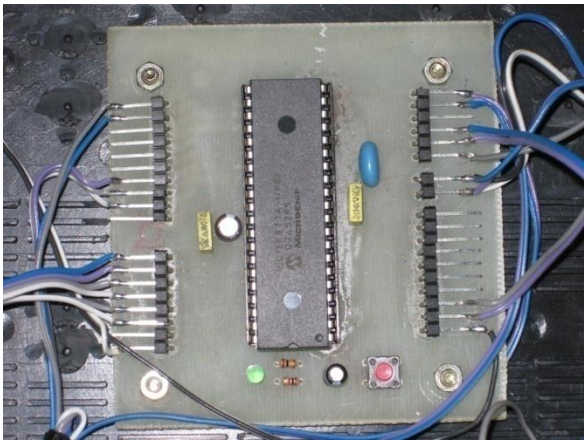
The device has two main boxes:



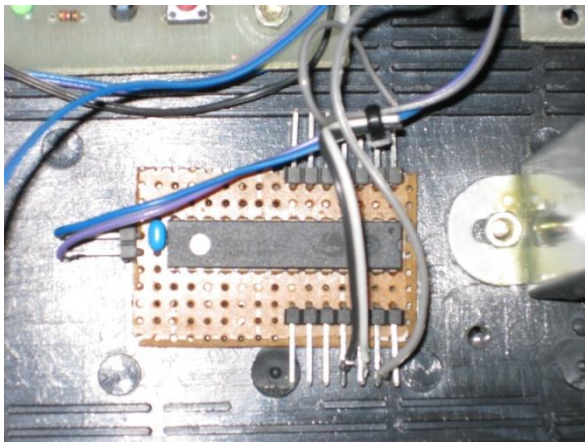
1. Black Box – serves as the main controller circuit where inputs are all inputted and entered to the device then process it. It houses the following components:



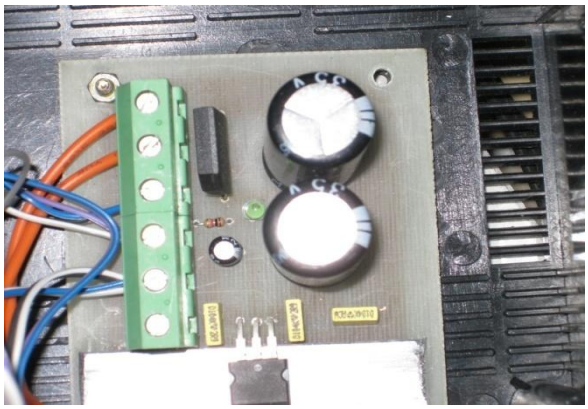
- Microprocessor Circuit – processes all the input and creates a corresponding output.



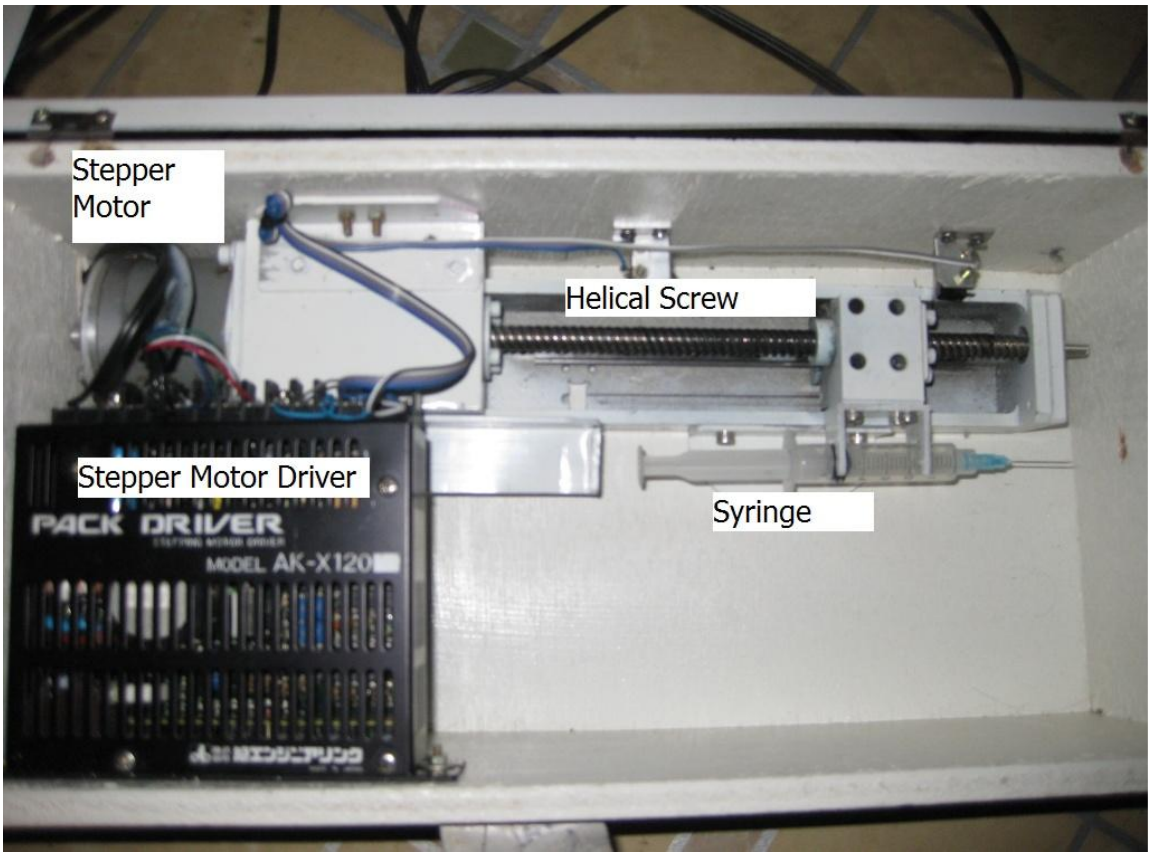
- PSOC Circuit



- Power Supply - the main power source of the device. Converts 220V AC to 5V DC power.



2. White Box – shows the output of the device.



Components:

- Stepper Motor Driver (black) – analyzes the output from the MCU and then converts it to action to be applied to stepper motor.
- Stepper Motor (stainless/aluminum) – the one that makes the helical screw to move and revolve.
- Helical Screw (white) – holds the syringe and makes the back and forth motion of it.
- Syringe Injection – serves as the container that holds the chemical or liquid to be controlled.